∂AG DYNAMIC ANALYSIS GROUP LLC
1440 LAKE FRONT CIRCLE, SUITE 130, THE WOODLANDS, TEXAS 77380, PHONE: (281) 419-6645, FAX: (866) 381-0196

BOCOUM (OUMAROU)
V.
DTNA-TRW

January 31, 2020

Report Prepared For:

Mr. Rob Cook
Goldberg Segalla
301 Carnegie Center Dr., Suite 200
Princeton, NJ 08540-6587

Mr. Philip McDaniel
Mr. Matthew Coveler
Weinstein Tippetts & Little
7500 San Felipe, Suite 500
Houston, TX 77063

Report Prepared By:

Nicholas J. Durisek

Nicholas J. Durisek, Ph.D., P.E.

Exhibit 1

TABLE OF CONTENTS

1.0 Introduction

1.1 General

I have been asked to determine the circumstances of the commercial vehicle crash that occurred on Friday, September 4, 2015 on Massachusetts Route 2 near its intersection with Factory Hollow Road in Franklin County, Massachusetts. As part of my analysis, I have been requested to determine how the crash happened, to reconstruct the crash with the available information, to analyze the data retrieved from the tractor, to analyze production documents, and to analyze the steering components of the subject vehicle.

As part of my analysis, I have reviewed materials related to this crash as listed at the end of this report. I have conducted inspections of the crash scene and the crash-involved, subject steering gear assembly. I have reviewed the available police information, photographs taken at the scene, and vehicle photographs. I have reviewed vehicle specifications, research conducted by others, and research that I have conducted. I have analyzed the available information and applied accepted engineering principles and techniques to better understand the circumstances of this crash, including the vehicles' motions, trajectories, and speeds at different times during the crash.

1.2 Qualifications

I earned a Bachelor of Science in 1992, a Master of Science in 1993, and a Doctor of Philosophy in 1997 in mechanical engineering at The Ohio State University in Columbus, Ohio, USA. In addition to my formal engineering training and including my graduate research, I have over twenty-seven years of automotive engineering experience. My area of specialization in my advanced degrees was large system design, specifically in the areas of vehicle dynamics and vehicle parameter measurement. My master's research and doctorate research focused on how to measure multiple vehicle characteristics simultaneously, accurately, and efficiently. My master's thesis was entitled *The Conceptual Design of a Vehicle Inertia Measurement Facility (VIMF)*. The VIMF is a machine used to measure fundamental characteristics of a vehicle, namely the longitudinal, lateral, and vertical vehicle center of gravity location, mass moments of inertia about the vehicle's roll, pitch, and yaw axes, and roll/yaw cross product of inertia. While working toward my doctorate, I organized and lectured an engineering course entitled *System Dynamics*. During the course of my research, I published a master's thesis, a dissertation, and peer-reviewed journal articles describing my research.

In 1997, after I earned my doctorate, I was hired by Ford Motor Company, headquartered in Dearborn, Michigan, as an engineer in Product Development. I performed design analyses, computer simulations, and testing for Ford, Lincoln, Mercury, and Jaguar vehicles primarily related to vehicle dynamics, ride control, and limit handling. I personally instrumented and tested vehicles at Ford's proving ground facilities in Arizona and Michigan and at MIRA in the United Kingdom, a test facility used by Jaguar Cars. I worked on the design and testing of braking system components, including components needed to satisfy the additional requirements and performance criterion of electronic stability control systems. I was part of the first projects at Ford Motor Company wherein an ESC system was being integrated into a passenger car and a light truck. I moved to the United Kingdom to transfer new technology developed by Ford Research to Jaguar Cars. As part of my responsibilities at Ford, I led the Safety Program Attribute Team (PAT) for what became the 2003 Lincoln Navigator. My responsibilities in this role included coordinating crash tests and sled tests and ensuring that the

Navigator's occupant restraint systems, including its airbags and seat belts, satisfied Ford's internal design criteria as well as government performance requirements.

Since 2001, I have been employed as an automotive engineering consultant, specializing in the analysis of crash reconstruction, failure analysis, vehicle dynamics, vehicle electronic stability control, advanced driver assistance systems, vehicle design, and vehicle crashworthiness and airbag deployment. As part of my work, I have conducted numerous crash tests including vehicle-to-barrier, vehicle-to-vehicle, and sled tests to evaluate, in part, overall vehicle motion, response, and crashworthiness. I have installed test equipment on vehicles and conducted on-track testing of various vehicle types, including passenger cars, pickup trucks, utility vehicles, vans, and medium trucks. I have performed numerous tests to evaluate vehicle performance before, during, and after the disablement of various steering components, suspension components, and tires. I have published peer-reviewed articles related to testing and research that I conducted.

In 2007, I formed Dynamic Analysis Group LLC located near Houston, Texas, USA. At Dynamic Analysis Group LLC, I continue to consult as an automotive engineer. I am a registered professional engineer in the State of Alabama, the State of Ohio, the State of South Carolina, and the State of Texas. I am an active member of the Society of Automotive Engineers (SAE) Vehicle Dynamics Standards Committee. Exhibit 01 contains my curriculum vitae that summarizes my background, training, and engineering experience that I use to draw conclusions and opinions. Exhibit 01 also includes my publication list and testimony list. All of the opinions in this report are expressed to a reasonable degree of engineering certainty and are based on my education, training, and experience that are outlined in my curriculum vitae. Dynamic Analysis Group LLC charges $385 per hour for my services. I reserve the right to supplement or modify my opinions if new information is received, and to supplement my opinions in response to the work and opinions of other experts.

2.0 <u>Crash Background</u>

2.1 General

According to police information and other information provided, this crash occurred at approximately 1:45 a.m. on Friday, September 4, 2015 on Massachusetts Route 2 (MA-2), otherwise known as Mohawk Trail, near its intersection with Factory Hollow Road, in Franklin County, Massachusetts. Mr. Oumarou Bocoum was driving a white 2007 Freightliner Columbia 120 tractor pulling a double-axle cargo trailer eastbound on MA-2. In the area of Factory Hollow Road, MA-2 for eastbound traffic was relatively straight and downhill, then it flattened as it curved right. As Mr. Bocoum approached the right curve, he steered his vehicle to the right but was traveling "at a high rate of speed and was unable to negotiate the curve."[1] Mr. Bocoum drove his tractor and trailer out of his travel lane, across the oncoming travel lane, and into the oncoming paved shoulder. The tractor and trailer were overturned driver's side leading and impacted the guardrail. They came to rest on the driver's side and in contact with the westbound guardrail of MA-2. The investigating officer "observed no skid marks from the truck or trailer…[and]… found a bottle of vodka and pep pills in the cab."[2] Mr. "Bocoum stated

[1] Commonwealth of Massachusetts Motor Vehicle Crash Report, p. 2.
[2] Massachusetts State Police Commercial Vehicle Crash Brief.

that the reason for the crash was weight shift."[3] The investigating officer concluded that the "crash was caused by operator error. Either the driver fell asleep or was impaired by a substance."[4] A satellite image of the roadway with the vehicle pre-impact travel direction and the vehicle area of rest is shown in Figure 1. Figure 2 shows the not-to-scale field diagram created by the police (rotated).

Figure 1. Aerial image of the roadway with travel direction annotated.

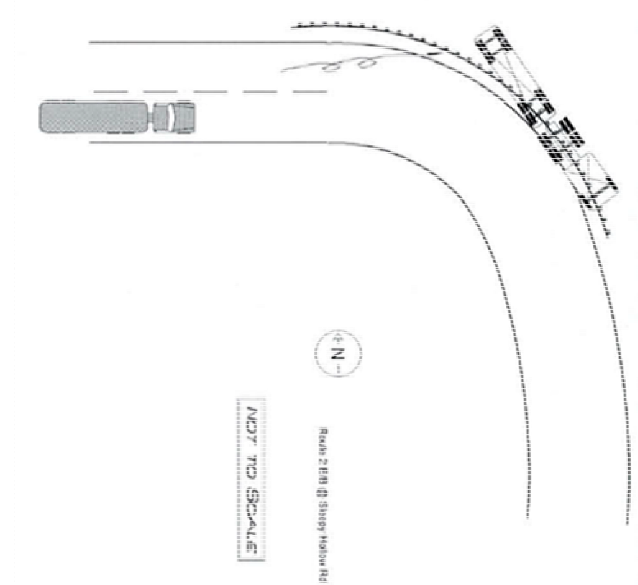

Figure 2. Police sketch, not to scale (rotated).[5]

2.2 Driver

Mr. Oumarou Bocoum was the driver of the 2007 Freightliner Columbia; at the time of the crash, he was 62 years old, maintained a valid commercial driver's license, and was reportedly belted. The Massachusetts police report listed two motor carrier violations that were in

---

[3] Commonwealth of Massachusetts Motor Vehicle Crash Report, DTNA-BOCOUM000713.
[4] Massachusetts State Police Commercial Vehicle Crash Brief, p. 1.
[5] Commonwealth of Massachusetts Motor Vehicle Crash Report, p. 5.

reference to Mr. Bocoum. One driver violation code was section 392.4(a), which stated, "Driver on duty and under the influence of, or using a narcotic drug / amphetamine, which renders the driver incapable of safe operation. Pep pills found in cab of truck during post crash inspection."[6] The second documented driver violation code was section 392.5(a)(3), which stated, "Driver in possession of intoxicating beverage while on duty or driving. Bottle of vodka found in cab during post crash inspection."[7]

Mr. Bocoum testified that there was "no traffic"[8] at the time of the crash and he had driven the route where the crash occurred "more than 50 times."[9] He testified that was traveling eastbound on MA-2 "and [he] stopped at [the Adams Road] light."[10] "When [the light] turn[ed] green, [he] took off, [he thought] about 900 feet, something like that." As he approached the curve, he testified that he "could not turn anymore, the truck was going straight… [and]…[his] steering wheel wasn't working at all."[11] "[He tried] to hit the brake to stop the truck and [he] hit the guardrail and [he continued] to flip."[12] Mr. Bocoum testified that he was able to apply the brakes, but "it was too late."[13] His employer told him that he was driving less than 35 miles per hour when he noticed the issue with the steering."[14] Trooper Welch reported, Mr. "Bocoum stated that the reason for the crash was weight shift."[15]

2.3 Crash Scene

I inspected the crash scene on August 21, 2019, and documented its condition with notes, photographs, video, and electronic measurements. The crash occurred in Franklin County, Massachusetts on MA-2 east of Factory Hollow Road. In this area, MA-2 is also known as Mohawk Trail and French King Highway. The approximate GPS coordinates of the crash area are: 42.616378º N, 72.552192º W. At the time of the crash, it was dark and clear, and the road surface was reported to be dry. MA-2 was generally oriented as an east-west roadway with one eastbound and one westbound travel lane. Approaching the area of the crash from the eastbound direction, MA-2 had a downhill grade that flattened and curved right, transitioning MA-2 into a south-north orientation. The speed limit on MA-2 in the area of the crash was 35 miles per hour; it had changed from 40 miles per hour in the downhill grade. Eastbound and westbound travel lanes were separated by a double yellow line with reflectors and had full width shoulders with rumble strips. The westbound shoulder was bordered by stone curbing and a close-proximity guardrail, and the westbound roadside had a downhill embankment that contained poles and trees. The guardrail that was damaged during the crash had been repaired prior to my inspection. The roadway was composed of traveled asphalt and was constructed with a crown and superelevation. No permanent visual obstructions were identified for eastbound traffic approaching the right curve; the curve was identified with a series of yellow chevron signs. The tree that was contacted by the trailer container and fractured during the crash sequence was still present at the time of my inspection.

---

[6] Massachusetts State Police Driver/Vehicle Examination Report, p. 1.
[7] Massachusetts State Police Driver/Vehicle Examination Report, p. 1.
[8] Deposition of Oumarou Bocoum, February 27, 2019, p. 127.
[9] Deposition of Oumarou Bocoum, February 27, 2019, p. 114.
[10] Deposition of Oumarou Bocoum, February 27, 2019, p. 107.
[11] Deposition of Oumarou Bocoum, February 27, 2019, p. 107.
[12] Deposition of Oumarou Bocoum, February 27, 2019, p. 107.
[13] Deposition of Oumarou Bocoum, February 27, 2019, p. 140.
[14] Deposition of Oumarou Bocoum, February 27, 2019, p. 136.
[15] Commonwealth of Massachusetts Motor Vehicle Crash Report, DTNA-BOCOUM000713.

During my inspection, I identified unique characteristics of the scene that were documented in photographs taken nearer the time of the crash. I electronically documented the characteristics of the scene using a FARO Focus3D laser scanner. I analyzed these measurements and created a scaled diagram of the crash scene as shown in Figure 3. A graphic representation of the scene measurements is shown in Figure 4. I did not identify any environmental conditions at the scene that would have caused the crash, although other crashes have occurred in this area.

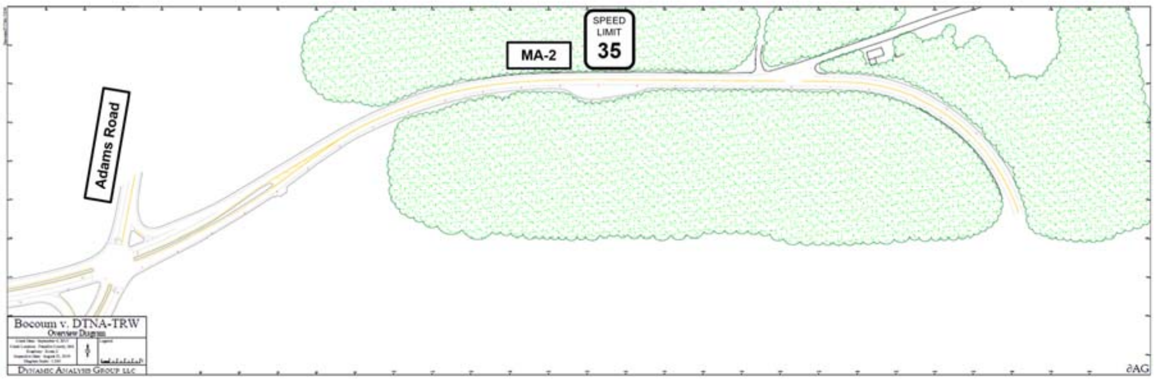

Figure 3. Overview diagram of the scene.

Figure 4. Graphic representation of measurements taken at the scene.

2.4 Vehicles Involved in the Crash

2.4.1 2007 Freightliner Columbia 120

The crash-involved Freightliner Columbia 120 was not available for inspection. The direct inspection of the vehicle's post-crash condition can provide information useful in determining the crash reconstruction. I have reviewed technical information and limited photographs of the crash-involved Freightliner Columbia 120. The vehicle was a white 2007 Freightliner Columbia 120 conventional cab having VIN 1FUJA6CK67LV21369. It was equipped with a 14.0 liter, inline six-cylinder engine. Available photographs indicate contact damage to the

upper left-front fender, the cab area, and the sleeper cab area. Photographs taken of the Freightliner Columbia in its post-crash condition are shown in Figure 5.

Figure 5. Crash involved Freightliner Columbia.

Damage to the upper left side of the vehicle was consistent with rollover contact with the asphalt roadway surface and guardrail. Front-to-rear roadway abrasions were present near the left-front fender area of the fiberglass hood. On the left side of the front bumper, roadway abrasions were present near the left-front tire, and the hood was misaligned with the front bumper. The front bumper was absent of evidence consistent with direct guardrail contact. The driver's door appeared bent and shifted. The cab and sleeper body panels were abraded and their structure was deformed and displaced. The driver's doorstep was bent, however the left side fuel tank appeared to be in its original position. The rear chassis structure appeared to be intact. Photographs showing the passenger's side and rear of the tractor were not available and no assessment of its condition could be made.

Contact damage was present on the left-front wheel and tire. Multiple abrasion patterns were present on the face of the rim near the wheel studs and wheel nuts; abrasions were visible on the wheel nuts. Abrasions present on the rim flange indicated contact forces from the outboard edge of the outer rim flange toward the center of the wheel. The left-front tire exhibited abrasions in the vicinity of the abrasions on the outer rim flange. The sidewall of the tire exhibited multiple abrasions in the same area as the contact damage on the outer rim flange. Figure 6 shows two photographs of the wheel and tire contact damage.

Figure 6. Left-front wheel and tire assembly from crash-involved Freightliner Columbia.

I have reviewed the GPS data that was reportedly associated with the crash involved Freightliner Columbia 120. The information was reported and distributed by Wireless Links Inc. in a route report for Oumarou 885 from 9/4/2015 12:00 AM to 9/4/2015 11:59 PM.[16] An excerpt of the Wireless Links Inc. route report is shown in Figure 7. The route report indicated the date, time, speed, direction, street, city, zip code, state, time stopped, distance, Emg. category, and battery voltage. The total distance traveled is shown to be 93.73 miles. The police reported time of the incident was 1:45 am.[17] The entry with a time of 01:36:03AM and a reported speed of 0.00 miles per hour on the route report indicated that the vehicle was stopped; no further movement was indicated until 5:13:16 AM. The 01:36:03AM entry likely indicates the vehicle at its point of rest. The next reported entry at 05:13:16AM was likely post-crash movement. The Wireless Links Inc. system report indicated a minimum reporting of two-minute intervals up to a maximum of ten-minute intervals prior to the crash. Twenty-seven reported line items were contained in the report prior to the time of the crash.

Distributed By: Wireless Links Inc. Phone: (201) 531-5906

Route Report for Oumarou 885 from 9/4/2015 12:00 AM to 9/4/2015 11:59 PM

Pionna

Oumarou 885

Time	Speed	Dir	Street	City	Zip	State	Stopped	Dist.	Emg.	Bat., V
09/04/2015 12:01:35AM	56.08	NE	I-91	Meriden	06450	CT		5.06		
09/04/2015 12:03:35AM	46.41	NE	I-91	Middletown	06457	CT		1.85		
09/04/2015 12:08:35AM	65.41	NE	I-91	Cromwell	06416	CT		5.30		
09/04/2015 12:13:35AM	60.11	NE	I-91	Wethersfield	06109	CT		5.34		
09/04/2015 12:18:35AM	54.58	NW	I-91	Hartford	06106	CT		5.07		
09/04/2015 12:21:36AM	46.52	NE	I-91	Hartford	06120	CT		2.80		
09/04/2015 12:26:36AM	62.64	NE	I-91	Windsor	06095	CT		4.46		
09/04/2015 12:31:36AM	62.99	NE	I-91	Windsor Locks	06096	CT		5.27		
09/04/2015 12:36:36AM	64.83	NW	I-91	Enfield	06082	CT		5.08		
09/04/2015 12:41:36AM	59.42	NW	I-91	Longmeadow	01106	MA		5.13		
09/04/2015 12:43:36AM	42.84	NE	I-91	Springfield	01108	MA		1.83		
09/04/2015 12:45:36AM	37.54	NW	I-91	Springfield	01105	MA		1.31		
09/04/2015 12:47:58AM	49.86	NW	I-91	Springfield	01107	MA		1.66		
09/04/2015 12:49:58AM	48.25	NW	I-91	Chicopee	01013	MA		1.56		
09/04/2015 12:52:10AM	49.98	NW	I-91	West Springfield	01089	MA		1.97		
09/04/2015 12:56:00AM	49.86	NE	I-91	Holyoke	01040	MA		3.40		
09/04/2015 12:59:22AM	49.63	NE	I-91	Holyoke	01040	MA		3.12		
09/04/2015 01:04:22AM	60.57	NW	I-91	Northampton	01060	MA		5.03		
09/04/2015 01:06:22AM	43.64	NE	I-91	Northampton	01060	MA		1.62		
09/04/2015 01:08:22AM	38.69	NW	I-91	Northampton	01060	MA		1.31		
09/04/2015 01:18:22AM	56.77	NE	I-91	South Deerfield	01373	MA		9.08		
09/04/2015 01:22:19AM	49.98	NW	I-91	Deerfield	01342	MA		3.81		
09/04/2015 01:24:19AM	45.49	NE	I-91	Deerfield	01342	MA		1.82		
09/04/2015 01:27:09AM	49.75	NW	I-91	Greenfield	01301	MA		2.37		
09/04/2015 01:30:03AM	49.86	NE	SR-2	Greenfield	01301	MA		2.66		
09/04/2015 01:32:03AM	49.29	SE	Mohawk Tr	Greenfield	01301	MA		1.40		
09/04/2015 01:34:03AM	32.93	NE	French King Hwy	Greenfield	01301	MA		1.65		
09/04/2015 01:36:03AM	0.00		French King Hwy	Greenfield	01301	MA	3:37:13	0.39		
09/04/2015 05:13:16AM	68.29	NE	Factory Hollow Road	Greenfield	01376			0.00		
09/04/2015 05:15:25AM	49.86	NE	Scout Road	Greenfield	01376			1.33		
09/04/2015 05:17:25AM	2.87	SW	Factory Hollow Rd					1.06		
							Total Distance:	93.73		

Figure 7. Wireless Links Inc. route report excerpt of Oumarou 885.

I analyzed the entries contained in the report. At 1:36:03AM, the data indicated a speed of 0.00 miles per hour, the direction was unreported, the location was French King Highway (MA-2), and the distance was 0.39 miles. This distance is likely the distance traveled from the prior data entry. The prior data entry was recorded at 1:34:03AM. At 1:34:03AM, the indicated a speed was 32.93 miles per hour, the direction was northeast, the location was French King Highway (MA-2), and the distance was 1.65 miles. The intersection of MA-2, French King Highway, and Adams Road was approximately 0.4 miles from the point of rest; MA-2 and French King Highway become a common road east of the Adams Road intersection. The speed recorded at 1:34:03AM, 32.93 miles per hour, was likely Mr. Bocoum's speed near the MA-2, French King Highway, and Adams Road intersection, not the speed that Mr. Bocoum was driving at the time

[16] Wireless Links Inc. route report, R. Salazar Deposition Exhibit, p. 68.
[17] Commonwealth of Massachusetts Motor Vehicle Crash Report, p. 1.

of the crash; Mr. Bocoum likely did not stop at the Adams Road intersection traffic light. Figure 8 illustrates the approximate distance between the Adams Road intersection and the point of rest.

Figure 8. Satellite image with route report data.

<u>2.4.2 1995 Hyundai Trailer and Trailer Container</u>

The crash-involved Hyundai trailer and trailer container were not available for inspection. The direct inspection of their post-crash condition can provide information useful in determining the reconstruction of the crash. I have reviewed technical information and limited photographs of the crash-involved Hyundai trailer. The trailer was a silver 1995 Hyundai forty-nine-foot container chassis having VIN 3H3C492SXST006787. Figure 9 shows a photograph of the subject trailer.

The trailer was carrying a forty-foot shipping container. The limited photographs showed that the left side of the container on the trailer contacted the guardrail and guardrail posts during the crash sequence. The sheet metal on the left side of the container was diagonally torn or cut from midway on the forward end of the left side of the container to the bottom corner at the rear of the container. Abrasions appeared to be present on the left side of the container as well. The forward facing side of the container near its top edge was deformed with evidence of narrow object contact damage. The recovery team invoice description stated that "the front of the trailer had impacted a 30 [inch] tree."[18] Figure 10 shows four photographs of the subject container from different angles. Approximately eighty-two rolls of paper were in the container at the time of the crash that reportedly weighed 43,898 pounds.[19] Photographs of the container's contents are shown in Figure 11.

[18] Rose Ledge Companies Invoice #5110911, p. 1.
[19] Seaman Paper Company of Massachusetts, Inc. Claim #PTL-115, p. 1.

Figure 9. Crash-involved Hyundai trailer.

Figure 10. Crash-involved trailer container.

Figure 11. Contents of crash-involved trailer container.

3.0 <u>2007 Freightliner Columbia: Steering Gear Assembly</u>

I inspected the crash-involved 2007 Freightliner Columbia steering gear assembly on September 12, 2019 in Newark, New Jersey. Prior to my inspection, the steering gear was removed from the subjected vehicle and disassembled. A photograph of the steering gear before it was removed from the vehicle is shown in Figure 12. The installed orientation of the steering gear assembly is an inverted mount, with the sector shaft located above the input shaft and worm screw axis. Only the steering gear was preserved and available for inspection; the pitman arm, draglink, and other essential steering system components were discarded and not available for inspection. At the time of my inspection, the steering gear assembly components were stored in a metal box that was locked with a security bolt. The steering gear assembly components were wrapped, bagged, and stored inside the box. I removed the components from the box, placed them on a table, and photographed them during my inspection.

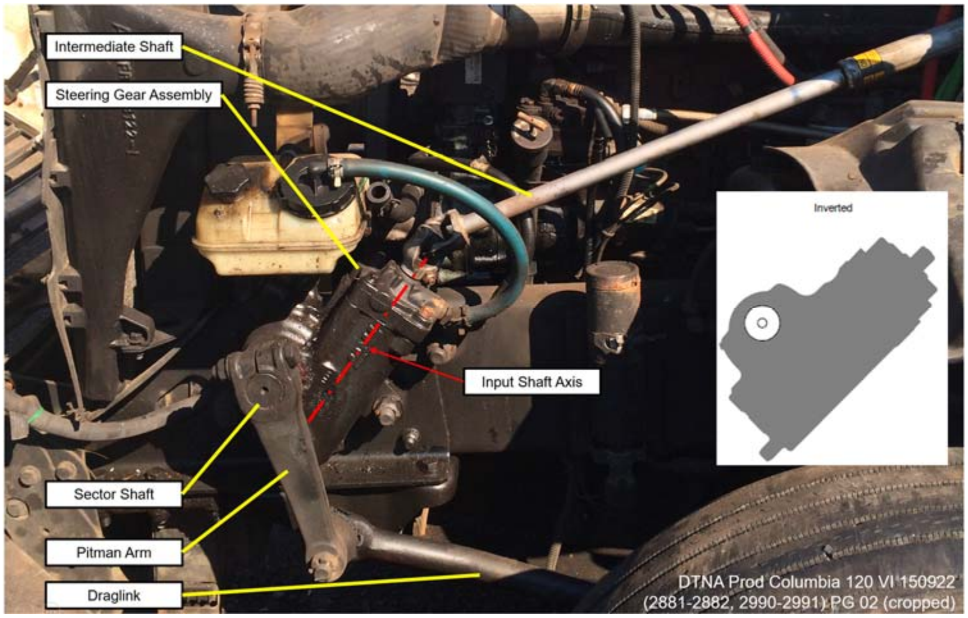

Figure 12. Steering gear assembly prior to removal (image cropped).

A steering gear section diagram of the subject steering gear is shown in Figure 13. The steering gear is designed to transmit steering inputs from the driver to the steering linkage that turns the road wheels. Driver steering inputs rotate the input shaft (Figure 13, No. 11) at the same angle and rate that the driver turns the steering wheel. The input shaft is connected to the worm screw (Figure 13, No. 15), which has a helix groove cut around its longitudinal axis that acts as a bearing race. Inside the rack piston (Figure 13, No. 14) is the companion helix groove of the worm screw, and recirculating balls (Figure 13, No. 13) that are located between the mating surfaces in the helix grooves of the worm screw and rack piston act as bearings. When the worm screw is rotated, the rack piston is translated axially along the worm screw's length.

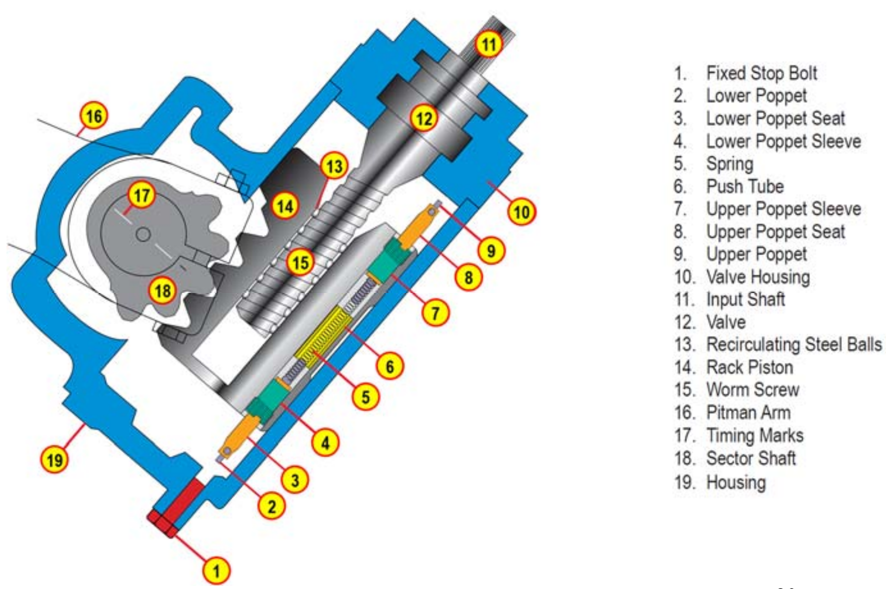

Figure 13. Steering Gear Assembly section diagram.[20]

[20] TRW Automotive Steering System Maintenance Guidelines (modified), p. 11.

Gear teeth cut into the rack piston mesh with gear teeth mounted on the sector shaft (Figure 13, No. 18); when the rack piston is translated, the sector shaft is rotated. Splines cut into the other end of sector shaft are used to mount the pitman arm, identified in Figure 12. Rotation of the pitman arm translates the draglink, Figure 12, which then turns the steering knuckle and moves the rest of the steering linkage. The mechanical movement of the rack piston is assisted by hydraulic fluid, thereby reducing the effort required for the driver to turn the steering wheel.

The worm screw was fractured at its end nearest the input shaft as shown in Figure 14. The fracture surfaces appeared uniform and were absent of post-fracture contact marks. No beach marks or signs of fatigue fracture were observed. Prior to my inspection, the worm screw had been cut into multiple pieces. The worm screw prior to being cut is shown in Figure 15. The helix bearing race exhibited deformation from high-force contact with the steel balls, or brinelling, on the side of the helix furthest from the input shaft. These marks were from significant axial impact forces applied to the worm screw in the direction away from the input shaft and valve housing (Figure 13, No. 10). The deformation from the loaded steel balls can be better seen on the segments shown in Figure 16. The impact load marks are consistent with the worm screw being put in tension.

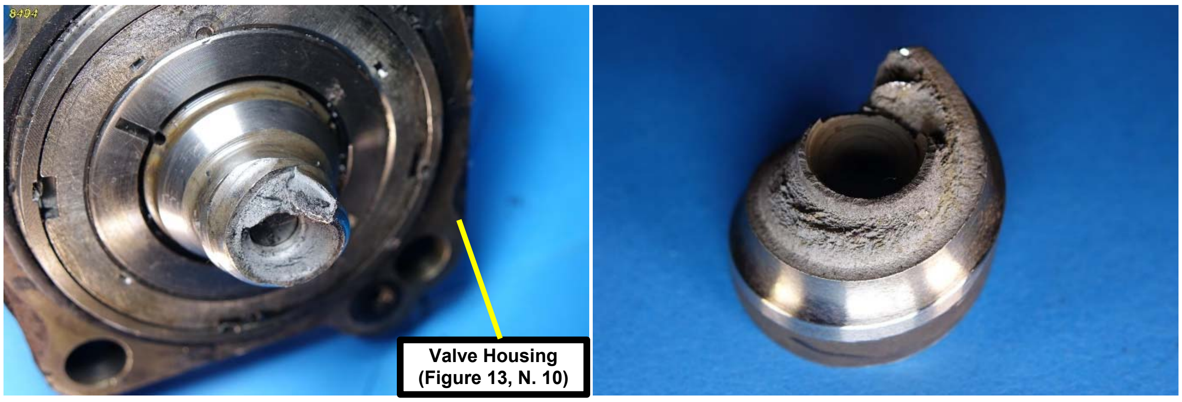

Figure 14. Worm screw fracture surfaces (cut segment on right).

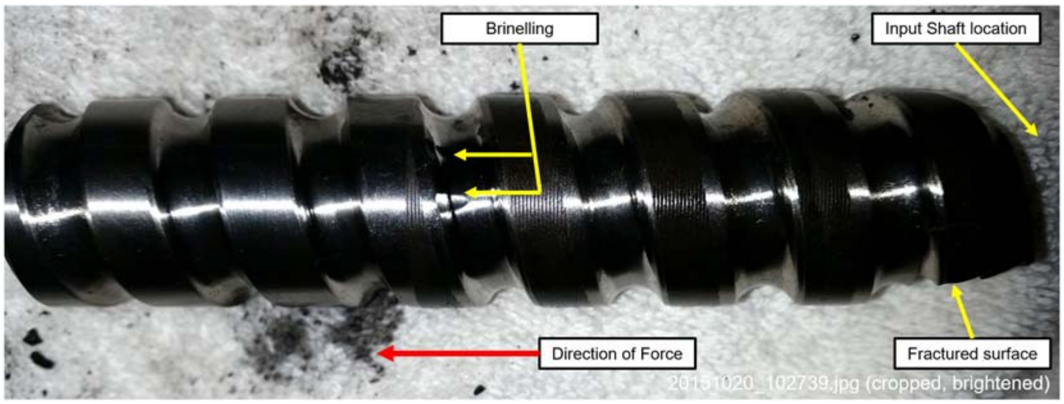

Figure 15. Worm screw with brinelling prior to being cut into multiple pieces.

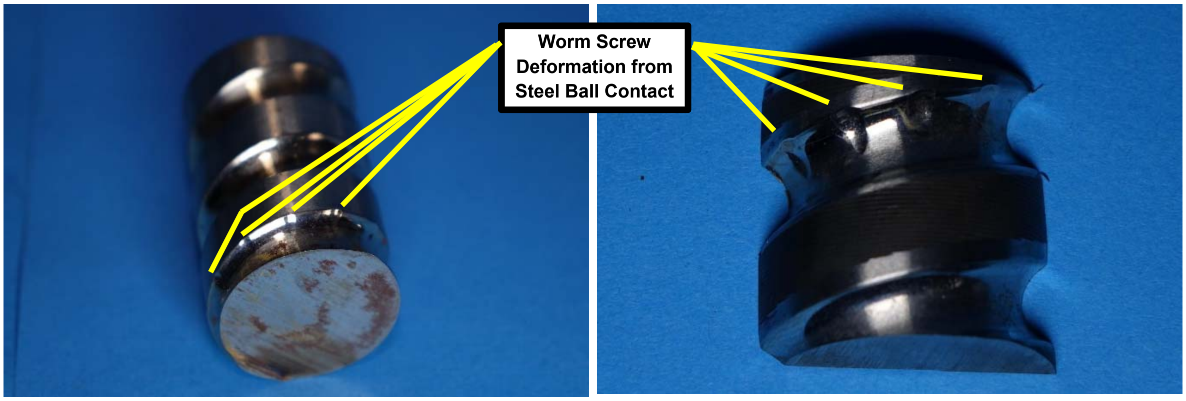

Figure 16. Worm screw deformation from steel ball contact.

Localized deformation was also present on the helix bearing surface inside the rack piston, as shown in Figure 17. The deformation was not visible on the surfaces of the helix that can be observed from the opening of the rack piston, but the deformation from steel ball contact was visible on the surface nearest the opening with a small inspection mirror. I did not observe wear on the edges of the indentations on the worm screw or in the rack piston that would be consistent with the balls passing over the indentations repeatedly during use.

Figure 17. Rack piston deformation from steel ball contact on input shaft side.

The sector shaft bearing race had localized deformation on the bearing race from the needle bearings and exhibited angled torsional cracks around the circumference of the sector shaft at the spline teeth of the drag link splines as indicated in Figure 18. The damage to the sector shaft is consistent with the sector shaft being loaded in a clockwise direction from a forward motion or force from the drag link, and this forward motion being resisted from within the steering gear. Given the geometry of the Freightliner steering linkage, the forward motion or clockwise rotation of the pitman arm is consistent with a forced left steer at the wheel end.

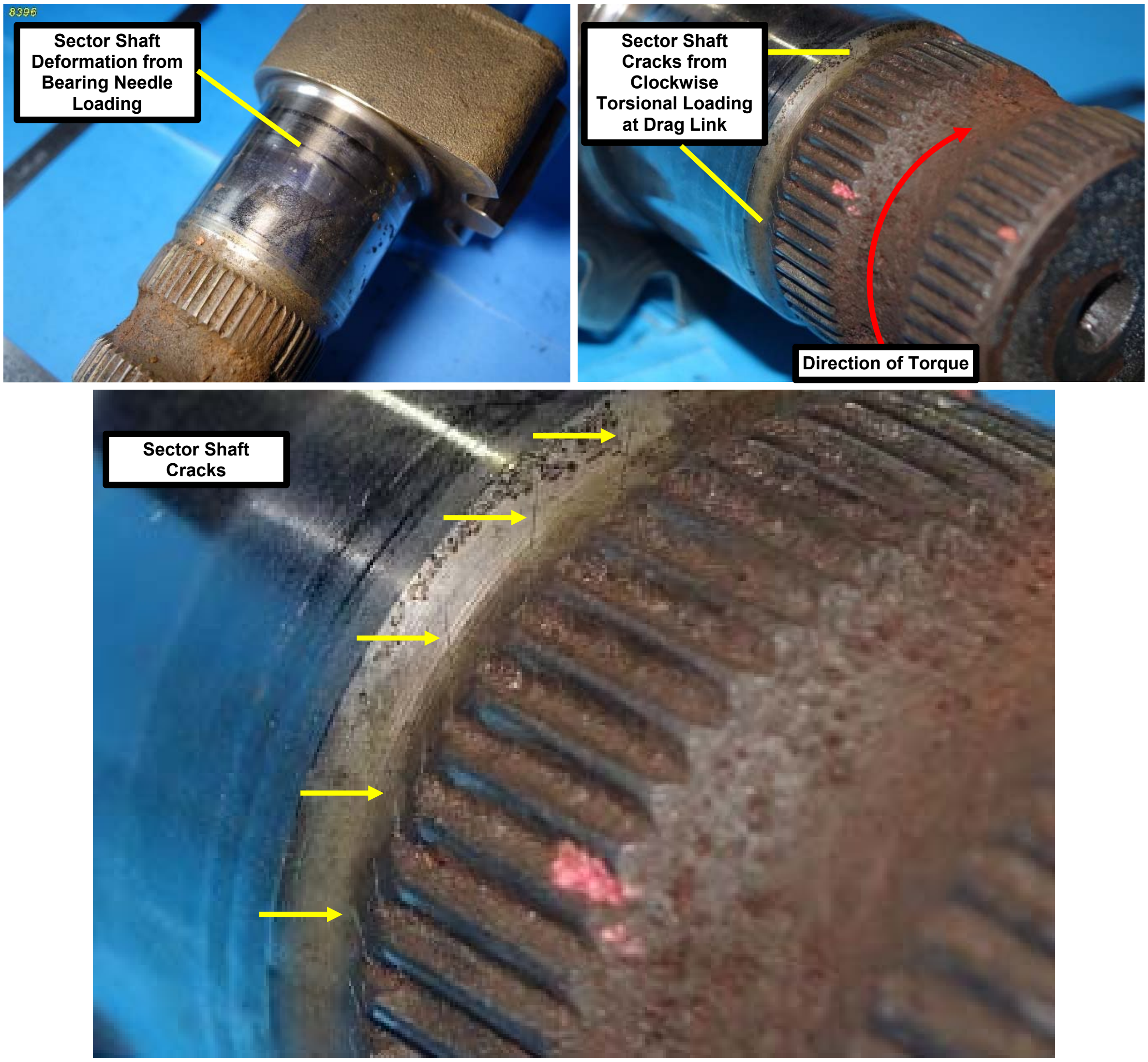

Figure 18. Sector shaft damage from loading and torsion.

The damage to the steering gear components is consistent with loading from the pitman arm being pushed forward (A in Figure 19), consistent with a forced left steer at the wheel end. The forward forces at the end of the pitman arm likely resulted in a combined clockwise torsional loading and radial loading at the sector shaft (B), and through the gear teeth, forces were applied to the rack piston (C) in direction away from the input shaft. These forces were transmitted to the worm screw through the recirculating balls that were between the rack piston and worm screw resulting in a tensile load on the worm screw (D); torsional loading would also be present due to the helix geometry between the worm screw and rack piston. The described load path is consistent with all the damage documented to the steering gear assembly components and resulted in the fracture of the worm screw at E, indicated below. The physical evidence to the steering gear components indicate that higher than design loads were imparted to the steering gear assembly during the crash sequence.

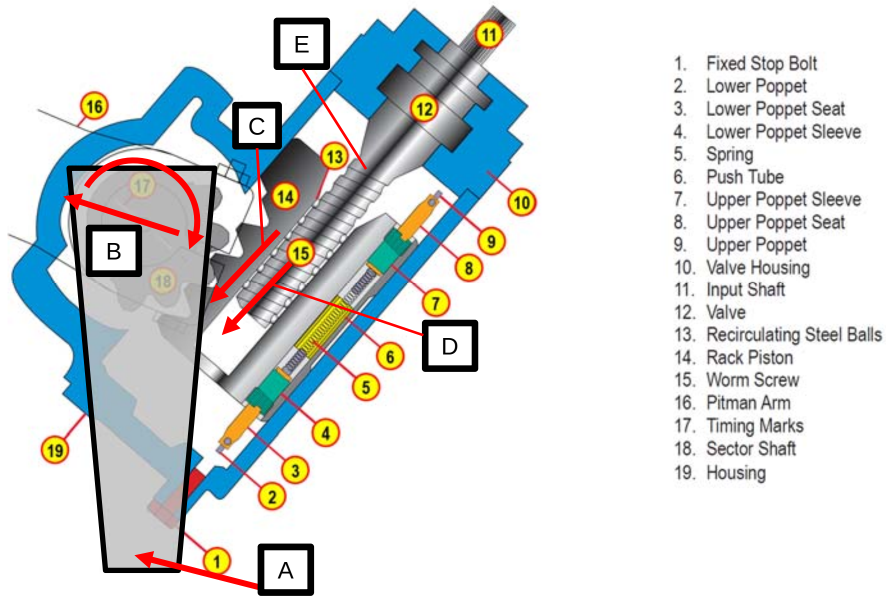

Figure 19. Steering gear assembly load path determine from damage analysis.

4.0 Crash Reconstruction

Using the physical evidence gathered from the scene inspection, parts inspection, vehicle and scene photographs, police information, accepted engineering principles and techniques, and all information that I have reviewed for this crash, I have determined the vehicles' most likely motion during the crash. Mr. Oumarou Bocoum was driving a white 2007 Freightliner Columbia 120 pulling a double-axle cargo trailer eastbound on MA-2 while carrying nearly 44,000 pounds of paper. Mr. Bocoum stated that he "stopped at a light"[21] immediately before the crash. The nearest traffic light to the area of the crash was the traffic light at the Adams Road intersection. The GPS information from Mr. Bocoum's tractor indicated that the vehicle was likely traveling at a speed of nearly 33 miles per hour in the area of the intersection; Mr. Bocoum likely did not stop at the Adams Road traffic light.

After driving through the Adams Road intersection, Mr. Bocoum continued eastbound on MA-2 and the roadway made a slight right turn that Mr. Bocoum successfully negotiated. In the area of Factory Hollow Road, MA-2 was relatively straight with a downhill grade for eastbound traffic, then it flattened as it curved to the right. As Mr. Bocoum approached the right curve on the downhill grade, he was likely driving 40 to 51 miles per hour and he did not maintain his travel lane. He drove out of the eastbound travel lane, drove across the westbound travel lane, and drove into the westbound shoulder while following an arc that was different than the geometry of his travel lane; he steered his vehicle right during this travel. While being driven on the shoulder, the cargo trailer with container and Freightliner Columbia 120 tractor were overturned driver's side leading and completed one-quarter revolution on the westbound shoulder, guardrail, and roadside. The trailer and container continued to travel over the guardrail and into the roadside area. The front side of the container near its upper edge impacted a tree. The container was detached from the front of the trailer at its point of rest. The trailer

[21] Deposition of Oumarou Bocoum, February 27, 2019, p. 107.

and container came to rest on the driver's side with the tractor chassis on the westbound shoulder and the cargo container on the roadside. No brake marks leading into the westbound shoulder were observed. Soon after the crash, Mr. "Bocoum stated that the reason for the crash was weight shift."[22] The police did not note that Mr. Bocoum could not steer.

The trailer and container fell on top of the W-beam guardrail and asphalt roadway during the overturn. The sheet metal on the left side of the trailer's cargo container was diagonally torn or cut with damage being higher on the forward end of the cargo container, shown in Figure 20 next to a three-dimensional representation of the cargo container damage. Using the available photographs, the approximate area where the W-beam guardrail damage began was determined and the diagonal cut on the side of the trailer's cargo container was graphically aligned with the top of the guardrail as shown in Figure 21. The orientation of the cargo container on the guardrail indicated that the left-rear of the cargo container was likely first to contact the guardrail. No physical evidence indicated that the trailer wheel and tire assemblies initially contacted the W-beam guardrail structure; it is unlikely that contact between the trailer wheel and tire assemblies and the guardrail initiated the overturn.

Figure 20. Crash involved cargo container (left) and three-dimensional representation of crash involved cargo container (right).

Figure 21. 2007 Freightliner Columbia 120 and cargo trailer area of contact with W-beam guardrail.

[22] Commonwealth of Massachusetts Motor Vehicle Crash Report, DTNA-BOCOUM000713.

The alignment of the physical evidence on the trailer cargo container with the guardrail was used to orient the tractor and trailer with the roadway when they were overturned and position the left-front tractor tire adjacent to the rumble strips on the shoulder. A photograph taken after the crash documents a tire mark with gouge marks in the pavement next to and on the rumble strips. These marks were likely created by the tractor's left-front tire and wheel after the tractor was overturned. The tire mark and gouges are indicated with yellow arrows in Figure 22. After the crash, the W-beam guardrail was not displaced away from the roadway to indicate it was driven into, instead it was displaced downward and into the roadway, indicating the trailer cargo container fell on top of the guardrail. The post-crash position of the guardrail is indicated with red arrows in Figure 22. Note the stone curb at the edge of the roadway, indicated with blue arrows in Figure 22, is between the guardrail and the roadside. Had the tractor and trailer been overturned due to interaction with the guardrail, given the height of the trailer as compared to the height of the guardrail, the guardrail would not have made the marks on the trailer cargo container as it did in this crash.

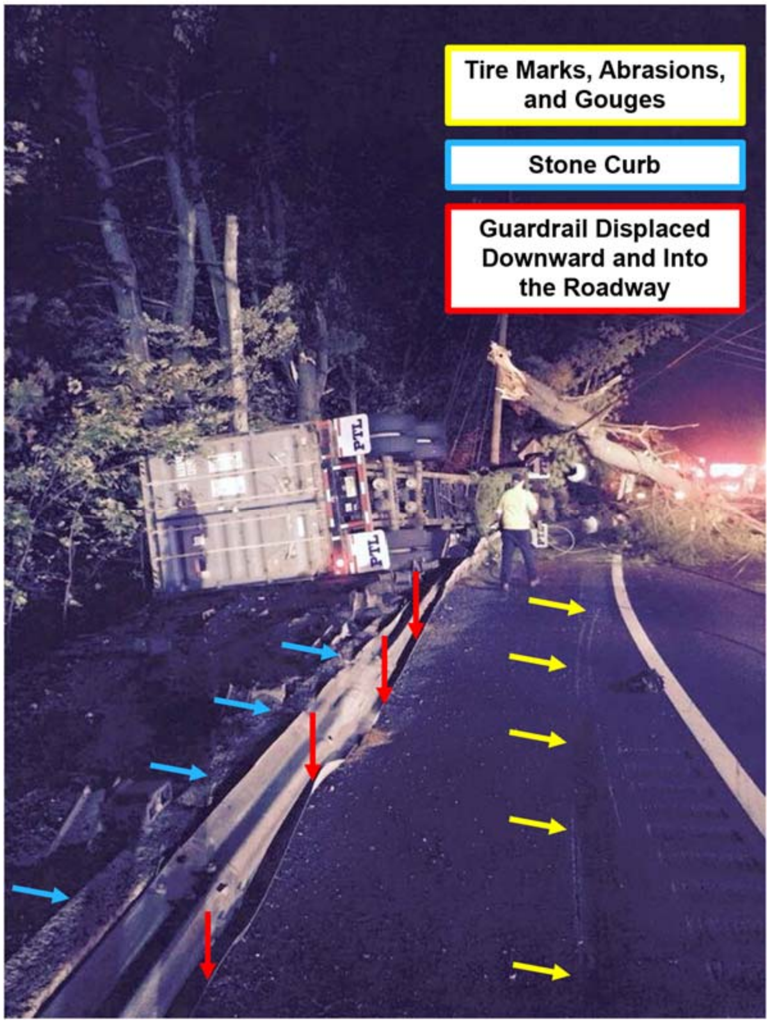

Figure 22. 2007 Freightliner Columbia 120 driver's side tire marks on roadway.

The location of the left-front tire mark indicated in Figure 22 is consistent with the vehicle's point of rest. The chassis and frame structure of the 2007 Freightliner Columbia 120 came to rest on the asphalt roadway in the MA-2 westbound shoulder. The upper cab and body structure

of the Freightliner tractor contacted the stone curb and guardrail during the crash sequence and came to rest partially on the shoulder, stone curb, guardrail and roadside. The area of rest of the 2007 Freightliner Columbia 120 and double-axle cargo trailer was determined using three-dimensional graphical analysis, shown in Figure 23. At rest, the left-front tire was located on the westbound rumble strips and the front wheels were turned left, as visible in Figure 24. Rim flange abrasions, wheel discoloration and abrasions, and wheel stud abrasions on the left-front wheel of the 2007 Freightliner Columbia 120 are indicated in Figure 25. Abrasions on the tire sidewall were also observed. The physical evidence from the left-front wheel and tire assembly is consistent with abrasions from the asphalt roadway and rumble strip surface during the crash sequence indicated in Figure 22. The forces created between the asphalt roadway and the wheel and tire assembly imparted left-steer forces to the steering system and steering gear; left-steer movement imparted from the road wheels forced the pitman arm forward. This loading that was generated as the left side of the tractor was crashed into the pavement and the wheel and tire engaged the rumble strip is consistent with the physical evidence present in the steering gear components, and likely caused the damage present in the steering gear, including fracturing the worm screw. The steering gear was likely broken after the vehicle was overturned.

Figure 23. 2007 Freightliner Columbia 120 and double-axle cargo trailer point of rest.

Figure 24. Freightliner tractor at rest with left-front wheel and tire on rumble strip turned left.

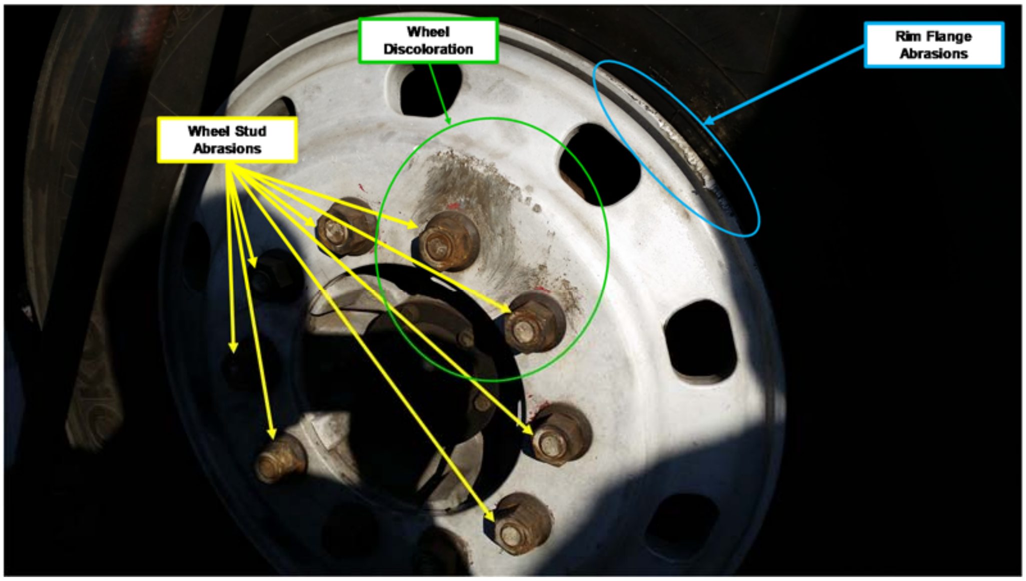

Figure 25. 2007 Freightliner Columbia 120 left steer axle wheel and tire assembly.

At rest, the steered wheels were turned left even though Mr. Bocoum steered right through a right turn. The physical evidence indicates that Mr. Bocoum had steering throughout his right steer and the Freightliner tractor responded to his steering inputs by turning right. The damage to the left side of the trailer cargo container and a lack of similar damage to the tractor, along with the other physical evidence, indicates that the trailer was likely tracking outside of the tractor at the time of overturn. The approximate distance between the locations where the cargo trailer container initially contacted the guardrail and the area of rest was likely between 110 and 120 feet. Figure 26 shows a three-dimensional graphic view of the crash sequence.

Figure 26. Top view of crash sequence.

Mr. Bocoum testified that he drove straight into the guardrail. If he drove straight into the guardrail as he testified, damage would have been present to the left-front bumper and the guardrail damage would have been more than 100 feet upstream of the crash location. The lack of damage to the left-front bumper and a matchup between the representative bumper height and the guardrail are shown in Figure 27; if Mr. Bocoum would have driven straight into the guardrail, the left-front bumper would have been damaged. The lack of damage to the left-front bumper indicates that the Freightliner tractor was steered away from the guardrail and did not make contact with the guardrail. The location where the cargo trailer container first contacted the guardrail demonstrates that Mr. Bocoum steered his tractor to the right and successfully negotiated a radius.

Figure 27. Lack of Freightliner bumper damage and Freightliner bumper matchup with the W-beam guardrail.

4.1 Review of Dr. McElroy's Report

I reviewed Dr. McElroy's report dated November 17, 2015 and found that his opinions to be inconsistent with the physical evidence from the crash. He provided no analysis on the crash sequence and did not reconstruct the crash. He stated that the forces in the crash were not consistent with the physical evidence, but he did not determine a crash sequence or reconstruction to determine if consistent forces would be present. He also stated, "Inspection of the 2007 Freightliner showed no evidence of impact damage to the tires or wheels which would have been responsible for the fracture of the worm shaft."[23] I agree that no evidence of a curb or guardrail impact was present on the left-front wheel and tire because the vehicle was steered away from the curb and guardrail and did not contact them. Instead, the wheel and tire forcibly interacted with the pavement and rumble strips with the energy of the tractor and trailer forcing relative motion, ultimately resulting in the left-front wheel and tire being turned left. The physical evidence on the left-front wheel and tire, along with the abrasions and a tire mark on the roadway, indicate contact and force transfer between the left-front wheel and tire as a result of the crash sequence. He also stated, "The worm shaft fractured while the Freightliner was being driven and failure of the worm shaft is responsible for the accident."[24] The physical evidence present on the vehicle and scene do not support this statement, and the lack of physical evidence on the left-front bumper further supports that Dr. McElroy's statement was untrue.

[23] Robert C. McElroy report, November 17, 2015, p. 2.
[24] Robert C. McElroy report, November 17, 2015, p. 2.

The physical evidence indicates that although Mr. Bocoum did not properly maintain his travel lane, he successfully steered his 2007 Freightliner Columbia 120 to the right, away from the curb and guardrail before he overturned his vehicle. The steering system was functional at the time Mr. Bocoum drove his tractor and trailer out of his travel lane, across the oncoming travel lane, and into the westbound shoulder.

4.2 Review of Mr. Grate's Report

I reviewed Mr. Grate's report dated November 12, 2015. He did not reconstruct the crash nor did he consider physical evidence that was available outside of the steering gear assembly. Because he limited the evidence that he considered to the steering gear assembly, he was unable to determine if the worm screw was fractured before or during the crash. He stated that the worm screw "failed as a result of or caused the accident."[25] He stated that the end of the bearings was embedded in the pinion shaft, which was consistent with my observations. Considering all the available physical evidence, the worm screw was likely fractured as a result of the tractor being overturned during the crash sequence and the left-front wheel assembly impacting the roadway and scraping shoulder and rumble strips.

5.0 <u>Closing</u>

In performing my analysis, I have determined that Mr. Bocoum was driving at a speed that was higher than the posted speed limit. Mr. Bocoum caused this crash by driving at excessive speeds, exiting his travel lane in a right curve, steering too much to regain his travel lane for his load and driven speed, and overturning his Freightliner tractor and cargo trailer onto the westbound shoulder, guardrail, and roadside. The worm screw in the steering gear assembly did not fracture before the overturn and the front of Mr. Bocoum's tractor did not impact the guardrail; Mr. Bocoum steered his vehicle to the right and his vehicle appropriately responded to his steering inputs. Physical evidence at the scene, on the cargo container, and on the tractor indicate that his trailer was overturned prior to guardrail contact when the left-front tire of the tractor was in close proximity to the westbound MA-2 white line.

The steering system on the 2007 Freightliner Columbia 120 was functional as designed prior to the vehicle being overturned. Forces imparted to the steering system through the left-front wheel and tire during the overturn forcibly turned the wheels left, consistent with the scrapes on the left-front wheel and tire and shoulder, cracks in the sector shaft at the pitman arm splines, bearing damage inside the rack piston, bearing damage on the worm screw, and the worm screw fracture. The physical evidence to the steering gear assembly components indicate higher than design loads were imparted to steering gear assembly in a forced left-turn motion. The worm screw fractured from the higher than design loads that occurred during the overturn. I identified no preexisting damage to the steering gear assembly components. The onboard recorded speed of 32.93 miles per hour was likely Mr. Bocoum's speed near the MA-2, French King Highway, and Adams Road intersection, not the speed that Mr. Bocoum was driving at the time of the crash; Mr. Bocoum likely did not stop at the Adams Road intersection traffic light.

[25] Frank Grate Report, November 12, 2015, p. 1.

All of the opinions in this report are expressed to a reasonable degree of engineering certainty and are based on my education, training, and experience that are outlined in my curriculum vitae attached hereto. I reserve the right to supplement or modify my opinions if new information is received or in response to the work and opinions of other experts.

6.0 Materials Received and Reviewed

Legal Documents

1. Discovery Confidentiality Order (03/12/19)
2. Letter - Pionna Transport to Weinstein Tippets & Little (05/15/19)
3. Plaintiff's Amended Verified Complaint
4. Answer to Plaintiff's Complaint on Behalf of Defendant DTNA
5. TRW's Answer to Plaintiff's Amended Verified Complaint
6. Eversource Energy Records (1249-1272)
7. Seaman Paper Company of Massachusetts Records (1288-1308)
8. Massachusetts Department of Transportation Records (1309-1317)
9. T-Mobile - No Records (1890)
10. Plaintiff's Initial Disclosures Pursuant to Rule 26
11. Joint Revised Scheduling Order (03/04/19)
12. Order Granting Extension of Deadlines (06/19/19)
13. TRW Produced Documents
14. DTNA Produced Documents
15. O. Bocoum - Abstract of Driving Record (970)
16. O. Bocoum - Pionna Transport Employment Application (744-757)
17. O. Bocoum - Driver's Daily Log (758-930)
18. O. Bocoum - Driver/Vehicle Examination Report (470)
19. Email Correspondence Regarding Container (934-937)
20. Article - MassLive Greenfield Police: Route 2 to be closed for much of day following tanker truck crash (09/21/15) (166-167) PDF
21. Article - WWLP.com Route 2 re-opened, hours after truck crash (09/04/15) (168-172) PDF
22. Pionna Transport Accident Register 2015
23. Rose Ledge Companies - Invoices and Payments (938-954)
24. Additional Crashes at Scene - Photographs and Articles

Responding Personnel

25. Massechusetts Crash Report
26. Massachusetts State Police - Commercial Vehicle Crash Brief - Redacted
27. Massachusetts State Police Transmittal Letter (09/26/17)
28. State Police Shelburne Falls Motor Vehicle Crash Report (707-716)
29. State Police Shelburne Falls - Administrative Journal Extract - Redacted
30. Greenfield PD Audio CD
31. Greenfield Fire Department Incident Report (696-701)
32. Greenfield Police Department Dispatch Records (703-706)
33. Montague Police Department - Call Log (718)
34. Turners Falls Fire Department Incident Report (967-969)
35. Massachusetts Department of State Police Records

Photographs and Video

36. Plaintiff Produced Photographs PDF
37. Plaintiff Produced Columbia 120 Vehicle Inspection Photographs
38. TRW Produced Columbia 120 Vehicle Inspection Photographs (10/20/15) (1-58) PDF

39. TRW Produced Photographs (64-71) PDF
40. TRW Produced Columbia 120 Vehicle Inspection Photographs (10/13/15) (90-93, 96-99, 102-105, 108-110, 176-190) PDF
41. TRW Produced Columbia 120 Report & Vehicle Inspection Photographs (10/20/15) (111-138) PDF
42. Rose Ledge Container Vehicle Inspection Photographs (Unknown Date) (955-966) PDF
43. World Email and Photographs (1318-1320) PDF
44. Aspen Container Vehicle Inspection Photographs (Unknown Date) (1246-1248) PDF
45. Greenfield Fire Department Photographs JPEGs
46. Greenfield Fire Department Photographs (1277-1287) PDF
47. QC Metallurgical Documents
48. QC Metallurgical Part Inspection Photographs (11/04/15)
49. Rose Ledge Container Vehicle Inspection Photographs (09/08/15) JPEGs
50. World Photographs JPEGs
51. Plaintiff Produced Photograph JPEG
52. DTNA Produced Photograph (2938) PDF
53. DTNA Produced Part Inspection Photographs (10/15) (2986-2989) PDF
54. DTNA Produced Columbia 120 Vehicle Inspection Photographs (09/22/15) (2881-2882, 2990-2991) PDF
55. TRW Produced Columbia 120 Vehicle Inspection Photographs (10/20/15) JPEG
56. Pionna Transport Columbia 120 Vehicle Inspection Photographs (Unknown Date) JPEG
57. Pionna Transport Produced Columbia 120 Vehicle Inspection Photographs (Unknown Date) PDF
58. R. McElroy Columbia 120 Vehicle Inspection Photographs (10/20/15) PDFs
59. T. Emerson Photographs JPEGs
60. T. Cheek Part Inspection Photographs (01/22/20) JPEGs
61. MTI Part Inspection Photographs (01/22/20) JPEGs

<u>Vehicle Information</u>

62. Annual Vehicle Inspection Report 2015
63. Columbia 120 - Freightliner Driver's Manual (1-203)
64. Columbia 120 - Freightliner Maintenance Manual (204-396)
65. Columbia 120 - Freightliner Invoice (03/08/06) (397-408)
66. Columbia 120 - Specifications (409-429)
67. Columbia 120 - Freightliner Warranty Booklet (430-458)
68. Columbia 120 - Warranty Registration and Coverage (459-469)
69. Columbia 120 - Detailed Inspection Report (09/25/15) (471-472)
70. Columbia 120 - Registration Records (672-676)
71. Columbia 120 - Title Records (677-690)
72. Columbia 120 - Secretary of State Records (691-695)
73. Columbia 120 - Vehicle Inspection and Maintenance Records
74. Columbia 120 - Metropolitan Trucking - No Records (717)
75. Columbia 120 - Maintenance Records (931-933)
76. Columbia 120 - North Jersey Truck Center - Records (719-740)

77. Columbia 120 - TRW Produced Part Inspection (Unknown Date) (604-607); (628-631); (856-882); (883-903) PDF Confidential

Medical Information

78. Medical - Pionna Transport Emails Regarding Medical Review

Depositions

79. T. Emerson (08/29/19)

Depositions and Exhibits

80. O. Bocoum (02/27/19); J. Cabrera (05/24/19); D. Foote (08/15/18); J. Gonzalez (05/21/19); Trooper A. Leonczyk (08/14/18); Captain K. Phelps (08/15/18); R. Salazar (02/28/19); Trooper J. Welch (08/15/18); Chief J. Zellmann (08/15/18); Trooper M. Tucker (08/29/19); B. Noah (9/16/19); C. Rieflin (10/11/19)

Witness Materials

81. F. Grate Produced Documents
82. R. McElroy Produced Documents

Reports and Attachments

83. F. Grate (11/12/15); R. McElroy (11/17/15)

7.0 Additional Information Reviewed

1. Vehicle information on the 2007 Freightliner Columbia 120 from VinLink and Diesel Truck Index.
2. Vehicle information on the 1999 Hyundai Container Chassis from VinLink.
3. Scene inspection: August 21, 2019.
4. Parts inspection: September 12, 2019.
5. Aerial images.
6. Commonwealth of Massachusetts Motor Vehicle Crash Report Coding.
7. Fricke, Lynn, *Traffic Accident Reconstruction*, First Edition.
8. Fricke, Lynn, *Traffic Crash Reconstruction*, Second Edition.
9. Warner, C. Y., et al., "Friction Applications in Accident Reconstruction," SAE Paper No. 830612.
10. Chen, H. F., et al., "Modeling of Rollover Sequences," SAE Paper No. 931976.
11. Cooperrider, N.K., et al., "Characteristics of Soil-Tripped Rollovers," SAE Paper No. 980022.
12. Orlowski, K.F., et al., "Reconstruction of Rollover Collisions," SAE Paper No. 890857.
13. Cooperrider, N.K., et al., "Testing an Analysis of Vehicle Rollover Behavior," SAE Paper No. 900366.
14. Larsen, R.E., et al., "Vehicle Rollover Testing, Methodologies in Recreating Rollover Collisions," SAE Paper No. 2000-01-1641.
15. Hughes, R.J., et al., "A Dynamic Test Procedure for Evaluation of Tripped Rollover Crashes," SAE Paper No. 2002-01-0693.
16. Luepke, P.E., et al. "Rollover Crash Tests on Dirt: An Examination of Rollover Dynamics," SAE Paper No. 2008-01-0156.
17. Luepke, P.E., et al., "Comparing Dolly Rollover Testing to Steer-Induced Rollover Events for an Enhanced Understanding of Off-Road Rollover Dynamics," SAE Paper No. 2011-01-1112.
18. McKibben, J.S., et al., "Development of Techniques to Prevent Occupant Ejection During Rollover–Volume I–Executive Summary," DOT HS-214-2-367, Oct 31, 1973.
19. Varner, R.W., et al., *Commercial Vehicle Accident Reconstruction and Investigation*, Second Edition, 2003.
20. Winkler, C.B., "Inertial Properties of Commercial Vehicles," Volume 2, UMTRI 83-17, April 1983.
21. Fang, H., et al., "Performance Evaluation of Strong Post Double-faced W-beam Guardrail and Strong Post Double-faced Thrie-Beam Guardrail at MASH Test Level 4 (TL-4) and Test Level 5 (TL-5) Conditions," NCDOT Project 2015-10, August 2017.
22. Winkler, C.B., "Rollover of Heavy Commercial Vehicles," UMTRI Research Review, Oct-Dec 2000, Vol. 31, No. 14.
23. Massie, D.L., "Short-Haul Trucks and Driver Fatigue," UMTRI-97-40, September 1997.
24. Videos of tractor trailer rollovers.
25. Rucoba, R., et al., "Analysis of Axle Shaft Failures for Use in Crash Reconstruction," SAE Paper No. 2005-01-1193.
26. Pascarella, R.J., et al., "Analysis of Tapered Roller Bearing Type Hub Separations in Motor Vehicle Crashes," SAE Paper No. 2007-01-0734.
27. Durisek, N.J., et al., "Analysis of Front Suspension Ball Joint Separations in Motor Vehicle Crashes," SAE Paper No. 2009-01-0101.

28. Dorren, L.K.A, et al., "Stem Breakage of Trees and Energy Dissipation During Rockfall Impacts," Tree Physiology, 26:63-71, 2006.
29. Asay, Alan F., et al., “Narrow Object Impact Analysis and Comparison with Flat Barrier Impacts”, SAE Paper No. 2002-01-0552.
30. Tanner, C. Brian, et al., “Pole and Vehicle Energy Absorption in Lateral Oblique Impacts with Rigid and Frangible Poles”, SAE Paper No. 2008-01-0170.
31. Woodson, W.E., et al., Human Factors Design Handbook, 1992.

In addition to the material listed, during the course of my career, I have reviewed numerous documents, materials, reports, and standards published by but not limited to: The Society of Automotive Engineers (SAE); The American Society of Mechanical Engineers (ASME); International Standards Organization (ISO); The Tire and Rim Association (TRA); texts and journals written by engineers and scientists, scientists and safety experts within the industry; and Notices, research reports, studies and Standards issued by the U.S. Department of Transportation concerning automobile design and research. These materials and documents also serve as part of the bases for my opinions.

8.0 <u>Exhibits</u>

01. Curriculum Vitae, Publication List, and Testimony List of Nicholas J. Durisek, Ph.D., P.E.

∂AG DYNAMIC ANALYSIS GROUP LLC
1440 LAKE FRONT CIRCLE, SUITE 130
THE WOODLANDS, TEXAS 77380
PHONE: (281) 419-6645

Nicholas J. Durisek, Ph.D., P.E.

Specialized Professional Competence

- Crash reconstruction and failure analysis.
- Vehicle dynamics, vehicle electronic stability control, vehicle dynamics testing and simulation, vehicle parameter measurement, advanced driver assistance systems, and advanced chassis systems.
- Design, testing, and evaluation of vehicle crashworthiness and airbag deployment; computer aided engineering, computer modeling of design, and design verification.
- Risk analysis of mechanical designs including the identification of failure modes and assessment of consequences of failure.

Professional Qualifications

- Doctor of Philosophy, Mechanical Engineering, The Ohio State University, 1997
  Dissertation: *Simultaneous Overall Measurement Uncertainty Reduction for Multi-Parameter Macro-Measurement System Design*
- Master of Science, Mechanical Engineering, The Ohio State University, 1993
  Thesis: *Conceptual Design of a Vehicle Inertia Measurement Facility (VIMF)*
- Bachelor of Science, Mechanical Engineering, The Ohio State University, 1992
- Dynamic Analysis Group LLC, Principal Engineer – 2007 to present
- Tandy Engineering & Associates, Inc., Engineer – 2003 to 2007
- S.E.A., Inc. (SEA, Ltd.), Senior Project Engineer – 2001 to 2003, Researcher (part-time) – 1993 to 1995
- Ford Motor Company (Jaguar Cars, Ltd.)
  Senior Project Engineer / Program Analyst – 1999 to 2001
  Product Development Engineer – 1997 to 1999
- The Ohio State University, Department of Mechanical Engineering
  Graduate Research Associate/Graduate Teaching Associate – 1993 to 1996
- Battelle Memorial Institute, Chemical Warfare Defense, Researcher– 1990 to 1992
- Professional Engineer: Alabama Registration No. 28024-E, Ohio Registration No. 66693, South Carolina Registration No. 22899, Texas Registration No. 104523
- Memberships: American Society for Engineering Education (ASEE); American Society of Mechanical Engineers (ASME); Society of Automotive Engineers (SAE), Ohio Society of Professional Engineers (OSPE), National Society of Professional Engineers (NSPE)
- Honors and Awards: University Fellowship, DuPont Fellowship, Tau Beta Pi, Pi Tau Sigma, Phi Kappa Phi, Golden Key National Honor Society

∂AG DYNAMIC ANALYSIS GROUP LLC
1440 LAKE FRONT CIRCLE, SUITE 130
THE WOODLANDS, TEXAS 77380
PHONE: (281) 419-6645

Nicholas J. Durisek, Ph.D., P.E.

PUBLICATIONS

"Automated Vehicle Disengagement Reaction Time Compared to Human Brake Reaction Time in Both Automobile and Motorcycle Operation," Dinges, J.T., and Durisek, N.J., SAE Paper No. 2019-01-1010.

"Analysis of Front Suspension Ball Joint Separations in Motor Vehicle Crashes," Durisek, N.J., Granat, K.J., Holmes, E.W., SAE Paper No. 2009-01-0101.

"Repeatability and Bias Study on the Vehicle Inertia Measurement Facility (VIMF)," Durisek, N.J., Granat, K.J., Heydinger, G.J., Guenther, D.A., SAE Paper No. 2009-01-0447.

"Industry Implementation of Automotive Electronic Stability Control (ESC) Systems," Durisek, N.J. and Granat, K.J., SAE Paper No. 2008-01-0593; *Journal of Passenger Cars: Electronic and Electrical Systems*, Section 7, Vol. 117, pp. 220-244, April 2009, Reprinted from SAE Vehicle Dynamics and Simulation 2008.

"Analysis of Tapered Roller Bearing Type Hub Separations in Motor Vehicle Crashes," Pascarella, R.J., Durisek, N.J., Linovitz, S.W., SAE Paper No. 2007-01-0734; *Journal of Passenger Cars: Mechanical Systems*, Section 6, Vol. 116, pp. 602-611, June 2008, Reprinted from SAE Accident Reconstruction 2007.

"Comparative Dynamic Analysis of Tire Tread Belt Detachments and Stepped Diameter ("Lumpy") Tires," Durisek, N.J., Tandy, D.F., Granat, K.J., Tandy, K.T., Pascarella, R.J., Carr, L., SAE Paper No. 2007-01-0846; *Journal of Passenger Cars: Mechanical Systems*, Section 6, Volume 116, pp. 846-854, June 2008, Reprinted from SAE Vehicle Dynamics and Simulation 2007.

"Vehicle Response Comparison to Tire Tread Separations Induced by Circumferentially Cut and Distressed Tires," Tandy, D.F., Granat, K.J., Durisek, N.J., Tandy, K.T., Baldwin, J.M., Pascarella, R.J., SAE Paper No. 2007-01-0733.

"An Analysis of Yaw Inducing Drag Forces Imparted During Tire Tread Belt Detachments," Tandy, D.F., Tandy, K.T., Durisek, N.J., Granat, K.J., Pascarella, R.J., Carr, L., Liebbe, R., SAE Paper No. 2007-01-0836.

"Automotive Restraint Loading Evidence for Moderate Speed Impacts and a Variety of Restraint Conditions," Tanner, C.B., Durisek, N.J., Hoover, T.D., Guenther, D.A., SAE Paper No. 2006-01-0900.

"Vehicle Characterization Through Pole Impact Testing, Part II: Analysis of Center and Offset Center Impacts," Durisek, N.J., Tandy, K.T., Claussen, J.S., Tanner, C.B., Brantman, R., Guenther, D.A., SAE Paper No. 2005-01-1186.

"Delta V, Barrier Equivalent Velocity and Acceleration Pulse of a Vehicle During an Impact," Cheng, P.H., Tanner, C.B., Chen, F.H., Durisek, N.J., Guenther, D.A., SAE Paper No. 2005-01-1187.

"Vehicle Characterization Through Pole Impact Testing, Part I: Vehicle Response in Terms of Acceleration Pulses," Durisek, N.J., Tanner, C.B., Chen, H.F., Guenther, D.A., SAE Paper No. 2004-01-1210.

"Pole Impact Speeds Derived from Bilinear Estimations of Maximum Crush for Body-On-Frame Constructed Vehicles," Chen, H.F., Durisek, N.J., Tanner, C.B., Guenther, D.A., SAE Paper No. 2004-01-1615.

"Effects of Loading on Vehicle Handling," Heydinger, G.J., Bixel, R.A., Durisek, N.J., Yu, Enyu, Guenther, D.A., SAE Paper No. 980228;*Journal of Passenger Cars*, Section 6, Vol. 107, pp. 407-415, February 1998, Reprinted

from Vehicle Dynamics and Simulation 1998, SP-1361, pp. 87-96. (Presented at the 1998 SAE International Congress and Exposition, Detroit, Michigan, February 23-26, 1998.)

"Land Vehicle Roll/Yaw Product of Inertia Measurement," Durisek, N.J., Heydinger, G.J., Chrstos, J.P., and Guenther, D.A., Proceedings of the Transactions of the ASME, *Journal of Dynamic Systems, Measurements, and Control*, Vol. 119, June 1997, pp. 212-216.

Simultaneous Overall Measurement Uncertainty Reduction for Multi-Parameter Macro-Measurement System Design, Durisek, N. J., Ph.D. Dissertation, The Ohio State University, March, 1997.

"Application of Uncertainty Methods for the Design of Multi-Parameter Macro-Measurement Systems," Durisek, N.J., Heydinger, G.J., and Guenther, D.A., Proceeding of the ASME Dynamic Systems and Control Division, DSC, Vol. 57-1, 1995 IMECE, pp. 471-480. (Presented at the 1995 ASME International Mechanical Engineering Congress and Exposition, San Francisco, California, November 12-17, 1995.)

"Calibration Fixture Design for Vehicle Center of Gravity Height and Inertia Measurements," Durisek, N.J., Heydinger, G.J., Bixel, R.A., VRTC Final Report, DTNH22-94-P-08424, April, 1995.

"The Design of a Vehicle Inertia Measurement Facility," Heydinger, G.J., Durisek, N.J., Coovert, D.A., Guenther, D.A., and Novak, S.J., *SAE Transactions*, 950309, New Developments in Vehicle Dynamics, Simulation and Suspension Systems, Reprinted from SP-1074, pp. 69-78. (Presented at the 1995 SAE International Congress and Exposition, Detroit, Michigan, February 27-March 3, 1995.) Also presented and reprinted by invitation at the 1995 Society of Allied Weight Engineers (SAWE) International Conference, Huntsville, Alabama, May, 1995.

"A Study of Vehicle Class Segregation Using Linear Handling Models," Sultan, M.O., Heydinger, G.J., Durisek, N.J., and Guenther, D.A., SAE Tech. Paper, 950307, New Developments in Vehicle Dynamics, Simulation and Suspension Systems, Reprinted from SP-1074, pp. 41-53. (Presented at the 1995 SAE International Congress and Exposition, Detroit, Michigan, February 27-March 3, 1995.)

"Developments in Vehicle Center of Gravity and Inertial Parameter Estimation and Measurement," Bixel, R.A., Heydinger, G.J., Durisek, N.J., Novak, S.J., and Guenther, D.A., *SAE Transactions*, 950356, February, 1995. Also presented and reprinted by invitation at the 1995 Society of Allied Weight Engineers (SAWE) International Conference, Huntsville, Alabama, May 1995.

"Non-Rigid Body Product of Inertia Measurement: Application to Land Vehicles," Durisek, N.J., Heydinger, G.J., Chrstos, J.P., and Guenther, D.A, DSC-Vol. 54/DE-Vol. 76, Transportation Systems, ASME, pp. 375-386. (Presented at the 1994 International Mechanical Engineering Congress and Exposition, Chicago, Illinois, November 6-11, 1994.)

"An Overview of a Vehicle Inertia Measurement Facility," Heydinger, G.J., Durisek, N.J., Coovert, D.A., Lawrence, R.D., Nowjack, J.A., and Guenther, D.A., 94SF034, Proceedings for the 27th ISATA Conference on Road and Vehicle Safety, pp. 327-334, ISBN 0947719660. (Presented at the 27th ISATA Conference, Aachen, Germany, October 31 – November 4, 1994.)

Conceptual Design of a Vehicle Inertia Measurement Facility (VIMF), Durisek, N. J., Master's Thesis, The Ohio State University, August, 1993.

Design and Analytic Analysis of a Magnetic Thrust Bearing, Durisek, N. J., Undergraduate Thesis, The Ohio State University, March, 1992.

∂AG DYNAMIC ANALYSIS GROUP LLC
1440 LAKE FRONT CIRCLE, SUITE 130
THE WOODLANDS, TEXAS 77380
PHONE: (281) 419-6645

Nicholas J. Durisek, Ph.D., P.E.

DEPOSITION & TRIAL TESTIMONY

Mathes (Tina) v. FCA US LLC, et al. Oklahoma County, Oklahoma	CJ-2014-2224	03/11/16
Costly (Lakiva) v. Nissan Parish of Ascension, Louisiana	14-244-BAJ-SCR	04/14/16
Robinson (Crystal), et al. v. FCA US LLC, et al. Parish of East Baton Rouge, Louisiana	624,186	06/14/16
Barralaga (Mario) v. Cooper Tire & Rubber Company, et al. Harris County, Texas	2015-03070	07/20/16
Smith (Ramona) v. FCA US LLC, et al. Eastern District of Texas, Texas	1:15-CV-0218	08/25/16
Pertile (Daniel), et al. v. TRW, et al. District of Colorado, Colorado	1:15-cv-00518-NY	09/16/16
Costly (Lakiva) v. Nissan Parish of Ascension, Louisiana	14-244-JWD-SCR	02/23/17 (Trial)
Chan (Francis) v. Budd (James), et al. Harris County, Texas	2015-18367	03/08/17
Pendergast (Thomas) v. Dyche Cook County, Illinois	10 L 004072	03/20/17
Pendergast (Thomas) v. Dyche Cook County, Illinois	10 L 004072	05/04/17 (Trial)
Guardiola (Mercedes) v. FCA US LLC Starr County, Texas	DC-14-489	01/24/18 (Hearing)
Chan (Francis) v. Budd (James), et al. Harris County, Texas	2015-18367	05/17/18 (Trial)
Rocha (Maria) v. Wal-Mart Bexar County, Texas	2016-CI-10692	09/06/18
Munoz (Elvia) v. Goodyear Dimmit County, Texas	13-06-12009-DCVAJA	09/18/18
Price (Glenda) v. General Motors LLC Western District of Oklahoma, Oklahoma	5:17-cv-00156-R	09/27/18
Idica (Heather) v. Hyundai Superior Court of Washington In and For Pacific County	17-2-00168-25	12/14/18

Paqpaqui Crash, October 2015 Malta		01/30/19 (Trial)
Munoz (Elvia) v. Goodyear Dimmit County, Texas	13-06-12009-DCVAJA	02/19/19 (Trial)
Scanlon (Lawrence R., III) v. Hyundai Beaufort County, South Carolina	2016-CP-07-622	06/10/19
White (Susan), et al. v. FCA US, LLC U.S. District Court Eastern District of Michigan, Southern Division	17-12320	07/11/19
Jones (Janice) v. Hyundai Orangeburg County, South Carolina	2015-CP-38-00397	10/31/19
Martinez (Irma) v. Continental Tire Santa Fe County, New Mexico	D-101-CV-2017-02187	11/08/19
Gilreath (Daniel) v. FCA US LLC Butler County, Ohio	CV 2018 07 1583	11/20/19